CLAIMS

1. A bonding method for bonding objects to be bonded which have a bonding portion formed of a metal, wherein

said bonding portions, which have a hardness of 200 Hv or less,

are contacted with each other and pressed in a solid phase at room temperature after treating said bonding portions with an energy wave which is an atom beam, an ion beam, or a plasma.

2. The bonding method according to claim 1, wherein said bonding portion is formed of gold.

3. The bonding method according to claim 1, wherein

said bonding portion of said object to be bonded is formed by forming a gold film on a surface of a base material having a hardness of 200 Hv or less, and

after said objects to be bonded are bonded together, said gold film is diffused into said base material.

4. The bonding method according to claim 3, wherein said object to be bonded is a semiconductor or a MEMS device in which said bonding portion comprises a plurality of metal bumps formed by forming said gold film on a surface of said base material, and said base material is copper, and after said objects to be bonded are bonded together, said gold film is diffused into the base material.

5. The bonding method according to any one of claims 1 to 4, wherein said energy wave is a low-pressure plasma.

6. The bonding method according to claim 5, wherein

at least one of said objects to be bonded is a semiconductor; and

said bonding portion of each of said objects to be bonded is subjected to plasma cleaning using said low-pressure plasma which is generated with electric field having alternating + and - directions generated by an alternating power supply before said objects to be bonded are bonded together in a solid phase at room temperature.

7. The bonding method according to claim 6, wherein said alternating power supply is an RF plasma generating power supply capable of controlling a value of a bias voltage Vdc.

8. The bonding method according to claim 6, wherein said alternating power supply is a pulsed wave generating power supply capable of controlling a pulse width.

9. The bonding method according to any one of claims 1 to 8, wherein said bonding portion of at least one of said objects to be bonded has a surface roughness Ry of 120 nm or more.

10. The bonding method according to claim 9, comprising:

a head for holding one of said objects to be bonded;

a stage for holding said other object to be bonded; and

a vertical drive mechanism for performing a position control with respect to at least one of said head and said stage in a direction substantially perpendicular to said bonding surface of said object to be bonded, and performing a pressing control,

wherein, when said objects to be bonded are bonded together, during the bonding, said vertical drive mechanism is driven to press said objects to be bonded, and thereafter, said vertical drive mechanism is stopped to hold a constant height of said head from said stage for a predetermined time.

11. The bonding method according to any one of claims 1 to 8, wherein, after said bonding portion of at least one of said objects to be bonded is subjected to leveling, said bonding portion of each of said objects to be bonded is treated with said energy wave, and thereafter, said objects to be bonded are bonded together in a solid phase at room temperature.

12. The bonding method according to claim 11, wherein said leveling is performed using said opposing object to be bonded before said objects to be bonded are bonded together.

13. The bonding method according to any one of claims 1 to 12, wherein

in a chamber having a reduced pressure,

while said bonding surfaces of said objects to be bonded are not placed facing each other, said bonding portions are treated with said energy wave, and thereafter,

at least one of said objects to be bonded is moved so that said bonding surfaces are placed facing each other, and thereafter,

at least one of said objects to be bonded is moved in a direction substantially perpendicular to said bonding surface to contact said bonding portions with each other, and bond said objects to be bonded together in a solid phase.

14. The bonding method according to any one of claims 1 to 13, wherein, when said bonding portion is treated with said energy wave, a metal electrode is provided at a position facing said bonding surface of at least one of said objects to be bonded, a metal film including a metal forming said metal electrode is formed on said bonding surface of said object to be bonded by sputtering, and said objects to be bonded are bonded together in a solid phase.

15. The bonding method according to any one of claims 1 to 14, wherein said bonding portion is formed in the shape of a contour, said bonding portion is surface-activated with said energy wave, and thereafter, said objects to be bonded are bonded together in a solid phase at room temperature, so that space surrounded in said shape of contour by said bonding portions is formed between said bonding surfaces of said objects to be bonded to enclose a predetermined atmosphere in said space.

16. The bonding method according to claim 15, wherein said bonding portion is formed of gold, or a gold film on a surface of a base material having a hardness of 200 Hv or less, and said gold or said gold film constituting said bonding portion of at least one of said objects to be bonded is a gold plating having a thickness of 1 μm or more.

17. The bonding method according to claim 15 or 16, wherein bonding is performed in a vacuum, so that a vacuum atmosphere is enclosed in said space.

18. The bonding method according to claim 15 or 16, wherein, after said surface activation of said bonding portion, a vacuum state of a

low-pressure chamber is replaced with filling gas, and said objects to be bonded are bonded in said filling gas to enclose said filling gas atmosphere in said space.

19. The bonding method according to any one of claims 1 to 16, wherein said objects to be bonded are bonded together in the atmospheric air.

20. The bonding method according to claim 19, wherein one of the objects to be bonded is an electrically functioning device which employs the bonding portion as an electrode, and

said bonding portion has a surface formed of gold or copper, said bonding portion of the object to be bonded is cleaned with said energy wave, and thereafter, an attached layer is formed on said bonding portion using gas, said bonding portions including an metal electrode are contacted with each other in the atmospheric air, the positions of said objects to be bonded are adjusted to optimum positions while said device is caused to electrically function, and thereafter, said objects to be bonded are bonded together in a solid phase at room temperature.

21. The bonding method according to claim 20, wherein one of said objects to be bonded is a light emitting element, a probe from a power supply is contacted with said bonding portion functioning as an electrode of said light emitting element, a light emitting point of said light emitting element is recognized using a recognizing means to adjust the position of said light emitting element to an optimum position while said light emitting element is caused to electrically function, and thereafter, said objects to be bonded are bonded together in a solid phase at room temperature.

22. The bonding method according to any one of claims 19 to 21, wherein one of said objects to be bonded is a chip, and said other object to be bonded is a wafer on which a plurality of said chips are to be mounted, and a plurality of said chips are continuously bonded to said wafer.

23. The bonding method according to claim 22, wherein, during the time when said chips are continuously bonded to said wafer, after a predetermined time has passed, said wafer is treated again with said energy wave, and thereafter, bonding of said chips to said wafer is resumed.

24. The bonding method according to any one of claims 1 to 23, wherein said object to be bonded is a chip or a wafer composed of a semiconductor or a MEMS device.

25. A device which is formed with the bonding method according to any one of claims 1 to 24, wherein said device is a semiconductor device, a MEMS device, or the like.

26. A bonding apparatus comprising:

a head for holding one of an objects to be bonded;

a stage for holding an other object to be bonded; and

a vertical drive mechanism capable of performing a pressing control with respect to at least one of said head and said stage in a direction substantially perpendicular to a bonding surface of said object to be bonded,

wherein said objects to be bonded which have a bonding portion formed of a metal, said bonding portion has a hardness of 200 Hv or less, are bonded together in a solid phase at room temperature by contacting said

bonding portions with each other and pressing said bonding portions after treating said bonding portions with an energy wave which is an atom beam, an ion beam, or a plasma.

27. The bonding apparatus according to claim 26, comprising an energy wave emitting means for generating said energy wave.

28. The bonding apparatus according to claim 26 or 27, wherein said bonding portion is formed of gold.

29. The bonding apparatus according to claim 26 or 27, wherein

said bonding portion of said object to be bonded is formed by forming a gold film on a surface of a base material having a hardness of 200 Hv or less, and

after said objects to be bonded are bonded together, said gold film is diffused into said base material.

30. The bonding apparatus according to claim 29, wherein said object to be bonded is a semiconductor or a MEMS device in which said bonding portion comprises a plurality of metal bumps formed by forming said gold film on a surface of said base material, and said base material is copper, and after said objects to be bonded are bonded together, said gold film is diffused into said base material.

31. The bonding apparatus according to any one of claims 26 to 30, wherein said energy wave is a low-pressure plasma.

32. The bonding apparatus according to claim 31, wherein

at least one of said objects to be bonded is a semiconductor; and

said bonding portion of each of said objects to be bonded is subjected to plasma cleaning using said low-pressure plasma which is generated with electric field having alternating + and - directions generated by an alternating power supply before said objects to be bonded are bonded together in a solid phase at room temperature.

33. The bonding apparatus according to claim 32, wherein said alternating power supply is an RF plasma generating power supply capable of controlling a value of a bias voltage Vdc.

34. The bonding apparatus according to claim 32, wherein said alternating power supply is a pulsed wave generating power supply capable of controlling a pulse width.

35. The bonding apparatus according to any one of claims 26 to 34, wherein said bonding portion of at least one of said objects to be bonded has a surface roughness Ry of 120 nm or more.

36. The bonding apparatus according to claim 35, wherein

said vertical drive mechanism is capable of performing a position control with respect to at least one of said head and said stage in a direction substantially perpendicular to said bonding surface of said object to be bonded, and

when said objects to be bonded are bonded together, during the bonding, said vertical drive mechanism is driven to press said objects to be bonded, and thereafter, said vertical drive mechanism is stopped to hold a constant height of said head from said stage for a predetermined time.

37. The bonding apparatus according to any one of claims 26 to 34, wherein, after said bonding portion of at least one of said objects to be bonded is subjected to leveling, said bonding portion of each of said objects to be bonded is treated with said energy wave, and thereafter, said objects to be bonded are bonded together in a solid phase at room temperature.

38. The bonding apparatus according to claim 37, wherein said leveling is performed using said opposing object to be bonded before said objects to be bonded are bonded together.

39. The bonding apparatus according to any one of claims 27 to 38, wherein

said bonding apparatus comprises, in a vacuum chamber:

said head;

said stage;

said vertical drive mechanism; and

a moving means for moving at least one of said head and said stage in a side direction,

wherein said energy wave emitting means is capable of performing said energy wave treatment with respect to each of said objects to be bonded separately,

in said vacuum chamber having a reduced pressure,

while said moving means causes said bonding surfaces of said objects to be bonded not to be placed facing each other, said bonding portions are treated with said energy wave, and thereafter,

at least one of said objects to be bonded is moved so that said bonding surfaces are placed facing each other, and thereafter,

at least one of said objects to be bonded is moved by said vertical drive mechanism in a direction substantially perpendicular to said bonding surface to contact said bonding portions with each other, and bond said objects to be bonded together in a solid phase.

40. The bonding apparatus according to any one of claims 26 to 39, wherein, when said bonding portion is treated with said energy wave, a metal electrode is provided at a position facing said bonding surface of at least one of said objects to be bonded, a metal film including a metal forming said metal electrode is formed on said bonding surface of said object to be bonded by sputtering, and said objects to be bonded are bonded together in a solid phase.

41. The bonding apparatus according to any one of claims 26 to 40, wherein said bonding portion is formed in the shape of a contour, said bonding portion is surface-activated with said energy wave, and thereafter, said objects to be bonded are bonded together in a solid phase at room temperature, so that space surrounded in said shape of contour by said bonding portions is formed between said bonding surfaces of the objects to be bonded to enclose a predetermined atmosphere in said space.

42. The bonding apparatus according to claim 41, wherein said bonding portion is formed of gold, or a gold film on a surface of a base material having a hardness of 200 Hv or less, and said gold or said gold film constituting said bonding portion of at least one of said objects to be bonded is a gold plating having a thickness of 1 μm or more.

43. The bonding apparatus according to claim 41 or 42, wherein

bonding is performed in a vacuum, so that a vacuum atmosphere is enclosed in said space.

44. The bonding apparatus according to claim 41 or 42, wherein, after said surface activation of said bonding portion, a vacuum state of a reduced pressure chamber is replaced with filling gas, and said objects to be bonded are bonded in said filling gas to enclose said filling gas atmosphere in said space.

45. The bonding apparatus according to any one of claims 26 to 42, wherein said objects to be bonded are bonded together in the atmospheric air.

46. The bonding apparatus according to claim 45, wherein one of said objects to be bonded is an electrically functioning device which employs said bonding portion as an electrode,

said bonding apparatus comprises:

said head for holding said functioning device;

said stage for holding said other object to be bonded;

said vertical drive mechanism for vertically moving at least one of said head and said stage;

a probe for causing said functioning device to electrically function;

a recognizing means for recognizing a function of said functioning device; and

an alignment table for correcting relative positions of said functioning device and said object to be bonded, and

said bonding portion has a surface formed of gold or copper, said

bonding portion of said object to be bonded is cleaned with said energy wave, and thereafter, an attached layer is formed on said bonding portion using gas, said bonding portions including an metal electrode are contacted with each other in the atmospheric air, said positions of said objects to be bonded are adjusted to optimum positions while said device is caused to electrically function, and thereafter, said objects to be bonded are bonded together in a solid phase at room temperature.

47. The bonding apparatus according to claim 46, wherein one of said objects to be bonded is a light emitting element, said probe is contacted with said bonding portion functioning as an electrode of said light emitting element, a light emitting point of said light emitting element is recognized using said recognizing means to adjust said position of said light emitting element to an optimum position while said light emitting element is caused to electrically function, and thereafter, said objects to be bonded are bonded together in a solid phase at room temperature.

48. The bonding apparatus according to any one of claims 45 to 47, wherein one of said objects to be bonded is a chip, and said other object to be bonded is a wafer on which a plurality of said chips are to be mounted, and a plurality of said chips are continuously bonded to said wafer.

49. The bonding apparatus according to claim 48, wherein, during the time when said chips are continuously bonded to said wafer, after a predetermined time has passed, said wafer is treated again with said energy wave, and thereafter, bonding of said chips to said wafer is resumed.